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(NASA-CR-161382) QUALIFICATION TEST
PROCEDURES AND RESULTS FOR HONEYWELL SOLAR
COLLECTOR SUBSYSTEM, SINGLE-FAMILY RESIDENCE
(Honeywell, Inc.) 43 p HC A03/NF A01

N80-20813

Unclas
CSCL 10B G3/44 46733

DOE/NASA CONTRACTOR
REPORT

~~DOE~~/NASA CR-161382

QUALIFICATION TEST PROCEDURES AND RESULTS FOR
HONEYWELL SOLAR COLLECTOR SUBSYSTEM, SINGLE-FAMILY
RESIDENCE

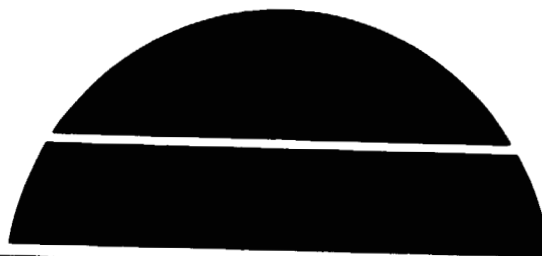
Prepared from documents furnished by

Honeywell, Inc.
Energy Resources Center
2600 Ridgway Parkway, N. E.
Minneapolis, Minnesota 55413

Under Contract NAS8-32093 with

National Aeronautics and Space Administration
George C. Marshall Space Flight Center, Alabama 35812

For the U. S. Department of Energy



U.S. Department of Energy



Solar Energy

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TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. DOE / NASA CR-161382	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.	
4. TITLE AND SUBTITLE Qualification Test Procedures and Results for Honeywell Solar Collector Subsystem, Single-Family Residence		5. REPORT DATE February 1977	
		6. PERFORMING ORGANIZATION CODE	
7. AUTHOR(S)		8. PERFORMING ORGANIZATION REPORT #	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Honeywell Inc. Energy Resources Center, 2600 Ridgway Parkway, N.E. Minneapolis, Minnesota 55413		10. WORK UNIT NO.	
		11. CONTRACT OR GRANT NO. NAS8-32093	
12. SPONSORING AGENCY NAME AND ADDRESS National Aeronautics and Space Administration Washington, DC 20546		13. TYPE OF REPORT & PERIOD COVERED Contractor Report	
		14. SPONSORING AGENCY CODE	
15. SUPPLEMENTARY NOTES This work was done under the technical management of Mr. J. Parker, George C. Marshall Space Flight Center, Alabama.			
16. ABSTRACT This document describes the test procedures and results in qualifying the Honeywell solar collector subsystem. Testing began in mid-August, 1976, and was concluded in late February, 1977. Testing was done in the following areas: pressure, service loads, hail, solar degradation, pollutants, thermal degradation and outgassing. Results from these tests are summarized in this report.			
17. KEY WORDS		18. DISTRIBUTION STATEMENT UC-59c <i>William A. Brooksbank Jr</i> WILLIAM A. BROOKSBANK, JR. Mgr, Solar Energy Applications Projects	
19. SECURITY CLASSIF. (of this report) Unclassified	20. SECURITY CLASSIF. (of this page) Unclassified	21. NO. OF PAGES 44	22. PRICE NTIS

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1. SCOPE

This document is submitted per item 500-13 of the contract data. Requirements List. It is the plan, i.e., schedule and procedures, that will be followed in qualifying the collector subsystem. Table 1 summarizes the tests involved.

2. SCHEDULE

Figure 1 is the schedule for qualifying the collector subsystem. Testing starts in mid August 1976 and ends in late February 1977, a 6.5 month period.

3. TEST PROCEDURES

The following detailed procedures define the tests that will be performed on the collector subsystem or elements thereof. Satisfying the prerequisites listed in Table 1 will qualify the collector subsystem for use in the heating and heating/cooling systems.

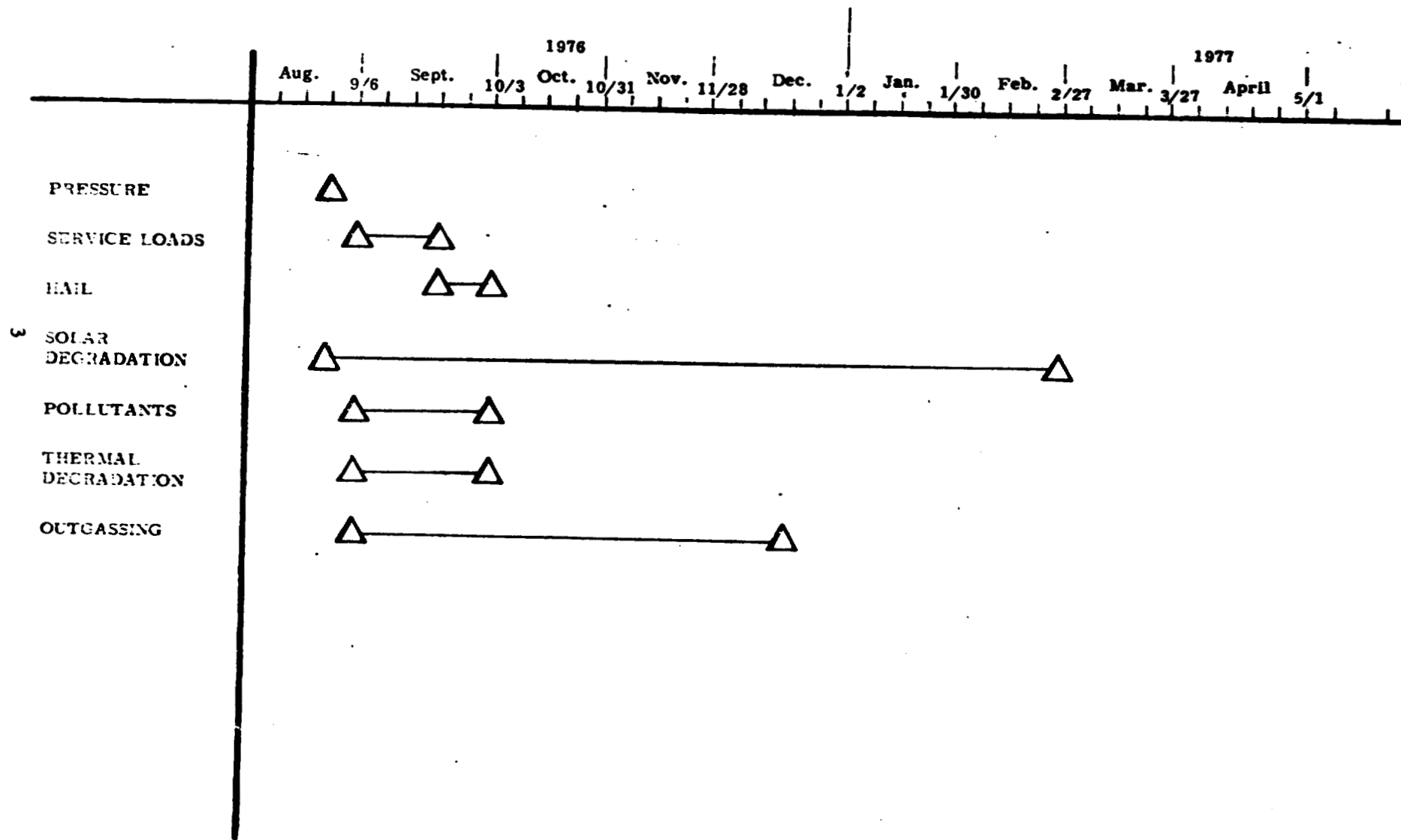
Attachment A to this document is the detailed test procedure for collector efficiency per Criterion 1.3.1 of Interim Performance Criteria (IPC) Document 98M10001 (28 February 1975). This will be a development rather than qualification test, but the results will bear on qualification of the collector subsystem.

Notification and witnessing will be per Quality Assurance Plan.

**TABLE 1. COLLECTOR SUBSYSTEM
QUALIFICATION TESTS**

Test/no.	Item Tested	Objective	Location	Prerequisite
Pressure 3.1	Collector-Lennox LSC18-1	Ascertain no leakage under hydrostatic pressure of 150 psig	Lennox	Less than 1 psi pressure drop in 15 minutes
Service Loads 3.2	Normally supported Collector-Lennox LSC18-1	Determine ability to withstand a distributed load of 50 PSF	ERC	No structural degradation or failure which would effect functionality
Hail 3.3	LSC18-1 Collector with glass-(2) 1/8" tempered P/N LB28284B	Determine ability to withstand impact of 1.25 inch ice sphere at 82 ft/sec.	ERC	No discernible fluid leakage of collector panel
2 Solar Degradation 3.4	2 collectors-Lennox LSC18-1	Measure efficiency after 1 month, examine. After 6 mos. at average 500 langley/day.	Efficiency- ERC. Aging- Las Vegas, NV or Phoenix, AZ	No excessive physical deterioration. Efficiency data obtained for design information.
Pollutants 3.5	Coupon specimens	Determine if: O ₃ , NaCl, SO ₂ NO _x HCl, degrade specimens	GAP	No significant finish degradation. Transmittance degradation less than 10%. Seal strength degradation less than 40%.
Thermal Degradation 3.6	Coupon specimens	Age at max, service temperature	GAP	No significant finish degradation. Transmittance degradation less than 10%. Seal strength degradation less than 40%.
Outgassing 3.7	Collector-Lennox	Determine if outgassing results from: 3 solar simulator cycles & 100 day-nite cycles.	ERC solar Simulator Las Vegas, NV or Phoenix, AZ	Transmittance must not degrade more than 10%.

FIGURE 1
COLLECTOR SUBSYSTEM
QUALIFICATION TEST SCHEDULE



3.1 Pressure Test - (IPC 2.3.1)

3.1.1 Test Levels

1 1/2 times working pressure (Ref. IPC 98M10001 2.3.2)
(1.5) 100 = 150 psig

3.1.2 Test Procedure

- o Connect hydraulic piston pump and gauge to inlet of collector
- o Pump fluid through collector until fluid exits the outlet.
- o Cap outlet
- o Increase internal pressure to $150 \begin{smallmatrix} +10 \\ -0 \end{smallmatrix}$ psig
- o Observe gauge for 15 minutes at constant temperature.
- o Record beginning and ending pressures on Qualification Test Data Sheet.

3.2 Service Loads - (IPC 3.1.2)

3.2.1 Test Levels

3.2.1.1 Dead Loads (D)

Include weight of material (negligible) and snow loads.

Ground snow - 40 psf (Ref: HUD 4930.1 601-5)

Roof Coefficient - 0.3 (Ref: HUD 4930.1 601-5)

$$D = (40) (0.3) = 12 \text{ psf}$$

3.2.1.2 Live Loads (L)

$$L = (15) (\cos 60^\circ)^* = 7.5 \text{ psf}$$

(Ref: HUD 4910.1 601-4.4)

* Based on collector tilt at Northern site which will yield worst case total loads due to snow component

3.2.1.3 Wind Loads (W)

$$W = 15 \text{ psf (Ref: HUD 4910.1 601-6.2 a, f)}$$

The worst case load combination is as follows: (Ref: IPC 98M10001 3.2.1)

$$P = (1.1)D + (1.3)L + (1.7)W$$

$$P = 13.2 + 9.75 + 25.5$$

$$P = 48.45 \text{ psf}$$

3.2.2 Test Procedure

- o Mount collector horizontally on a simulated roof mount which supports the collector as installed.**
- o Distribute sand bags approximately 30 lb. each uniformly on surface of collector until a distributed load of 50^{+5}_{-0} psf has been attained.**
- o Examine and record the location and extent of any plastic deformation or failure that occurs.**
- o Record on Qualification Test Data Sheet.**
- o For information only continue to load until plastic deformation occurs.**

3.3 Hail Size and Loading - (IPC 3.7.1)

3.3.1 Test Levels

Mean annual days with hail = 4

(Ref: IPC 98M10001 Figure 3.7.1)

Simulated hail size:

$d = (0.3) (4) = 1.20$ inches

(Ref: IPC 98M10001, 3.7.1)

Hail Velocity -- 1.25 inch hail = 82 ft/sec.

(Ref: NBS Building Science Service 23, Table 1)

Note: The above levels will qualify the material for areas of the United States except the Western Plains and some Rocky Mountain Areas. Using the above references, levels for these areas are:

Western Plains -- 2 inch diameter, 105 ft/sec.

Rocky Mountains (Denver area) -- 2.5 inch, 117 ft/sec.

Rocky Mountains (Cheyenne area) -- 3.0 inch, 130 ft/sec.

3.3.2 Test Procedure

The following procedure is in addition to the test method and test set-up described in National Bureau of Standards, Building Science Services, Number 23, August 1969.

- Set-up specimen stand timing section, and compressed gas launcher as shown in Figure 2 of referenced document (Separate timing section and launcher by about 10 ft.)
- Prepare about 12 simulated hailstones of 1.25 ± 0.05 inch diameter.
- Place 1/2 inch plywood in specimen stand and launch several hailstones at different launcher pressures until the pressure corresponding to $82 \pm \frac{8}{0}$ ft/sec. is demonstrated to be repeatable.
- Fill collector with fluid (leave small amount of air for expansion) and cap.
- Remove plywood and install collector in stand.
- Launch a 1.25 ± 0.05 inch hailstone at $82 \pm \frac{8}{0}$ ft/sec.
- Examine and record condition of specimen on Qualification Test Data Sheet.
- For Engineering information only; repeat above procedure at the following test levels, or until glass fracture occurs..

1. 2.0 ± 0.1 inch,	$105 \pm \frac{10}{0}$ ft/sec.
2. 2.5 ± 0.1 inch,	$117 \pm \frac{11}{0}$ ft/sec.
3. 3.0 ± 0.1 inch,	$130 \pm \frac{13}{0}$ ft/sec.

3.4 Solar Degradation - (IPC 5.1.1)

3.4.1 Test Levels

3.4.1.1 Part A. The requirements of the Interim Performance Criteria will be met by the outdoor exposure option of Section 03 page 65 of NASA Document 98M10001. Six months exposure of a collector in the Phoenix or Las Vegas area where it has been established that mean daily solar radiation exceeds 500 langleys.

3.4.1.2 Part B. The requirements of Part B will be met by measuring the efficiency of a collector before and after a one month exposure at the same site.

3.4.2 Test Procedure

- Ship two collectors to a test site near either Phoenix, Arizona or Las Vegas, Nevada after measuring efficiency, as described in Appendix A of this document.
- Install both collectors in an exposed position facing due south and tilted at an angle of 25° to the horizontal.
- Age both collectors in this position with no fluid in the tubing.
- After aging for 30 to 32 days, ship one collector back to ERC, Minneapolis.
- Conduct efficiency test on collector as described in Appendix A of this document.
- Record results on Qualification Test Data Sheet.

- After aging for 130 - 182 days, ship the other collector back to ERC, Minneapolis.
- Examine for degradation of seals and finishes and conduct efficiency test as described in Appendix A of this document.
- Record findings on Qualification Test Data Sheet.

3.5 Airborne Pollutants - (IPC 5.1.3)

3.5.1 Test Levels

500 hours	Ozone Atmosphere	50 \pm 5 pphm/vol
500 hours	Salt Spray	5 NaCl/95 H ₂ O
500 hours	Sulfurous Acid (H ₂ SO ₃)	100 ppm
500 hours	Nitric Acid (HNO ₃)	100 ppm
500 hours	Hydrochloric Acid (HCl)	100 ppm

3.5.1.1 Test Specimens

Coupon Samples (major dimension approximately six inches to 15 inches of the following collector parts.

Collector Pan	LB28287B
Seal Strip	40A2201
Glass	LB28283D
Frame	40A2601

3.5.1.2 Temperature Cycling

For all specimens:

Ozone exposure will be at 73.4 \pm 3.6°F

Salt spray will be at 95.0 \pm 2°F
-3

H₂SO₃

HNO₃

HCl

} repetitively cycled with one hour
at each of the following temperatures:

1 hour at $73.4 \pm 3.6^{\circ}\text{F}$

1 hour at $180 \pm 9.0^{\circ}\text{F}$

1 hour at $73.4 \pm 3.6^{\circ}\text{F}$

1 hour at $80.4 \pm 4.0^{\circ}\text{F}$

3.5.2 Test Procedure

Ozone: Ref. ASTM D-1149-64 (1970)

- o Conduct test per reference
- o Record all data on Qualification Test Data Sheet

Salt Spray: Ref. ASTM Standard Method B-117-73

- o Conduct test per reference
- o Record all data on Qualification Test Data Sheet

SO₂, NO₂, HCl

- o Prepare four beakers each of an aqueous solution of 100 ppm H₂SO₃, HNO₃ and HCl.
- o Immerse one each of each component part in each acid solution.
- o Place all 12 beakers in a temperature chamber and cycle between the stated temperature limits.
- o After 500 hours of cycling remove and examine for degradation.

3.5.3 Examination Procedure

After all exposures examine exposed and unexposed areas:

- o Visually examine all finishes for degradation.
- o Test seal strength P/N40A2201 with a tensile strength tester in accordance with ASTM D638-72.
- o Measure transmittance of glass using a spectrophotometer and method of ASTM E424.
- o Record all data on Qualification Test Data Sheet.

3.6 Thermal Degradation - (IPC 5.2.1)

3.6.1 Test Levels

Coupon specimens (major dimension approximately six inches to 15 inches) of the following parts will be thermally aged at the following maximum service temperature for a period of 500 hours.

<u>Part</u>	<u>P/N</u>	<u>Maximum Service Temp.</u>
Glass	LB28283D	280°F
Seal Strip	40A2201	280°F
Frame	40A2601	280°F
Absorber plate	LB28282A	480°F

3.6.2 Test Procedure

- o Place coupon specimens in controlled temperature chambers.
- o Age at temperature listed above for 500 hours minimum.
- o Inspect for mechanical and finish degradation.
- o Conduct tensile strength test per ASTM D638-72 on both aged and unaged specimens of the Seal Strip P/N 40A2201.
- o Measure transmittance of glass, both aged and unaged specimens ASTM E424.
- o Record all data on Qualification Test Data Sheet.

3.7 Transmission Losses Due to Outgassing - (IPC 5.2.6)

3.7.1 Test Levels

Cycling to maximum service temperature will be accomplished by two means:

- 1) Three cycles using the Solar Simulator
- 2) 100 cycles under actual outdoor exposure in Phoenix, Arizona or Las Vegas, Nevada where the mean daily solar radiation exceeds 500 Langleys.

3.7.2 Test Procedure

3.7.2.1 Part I

- o Measure transmittance of collector glass by making 18 pyranometer readings in front of and to the rear of the glass on a one foot grid while the glass is exposed to natural sunlight.
- o Install a collector without fluid on stand in the solar simulator facility such that it is normal to the radiation and at least eight feet from the light source.
- o Instrument the collector plate with a thermocouple mounted on the back surface of the plate.
- o Increase simulated solar flux gradually to a value of $250 \pm 25 \text{ Btu/hr-ft}^2$. Vary the rate of increase to achieve maximum plate temperature in two hours.
- o Maintain flux for two hours.

- Gradually reduce flux to zero to achieve room temperature of the plate in 2 hours.
- Repeat this cycle 3 times.
- At the end of three cycles inspect for the presence of condensation on glass. Measure transmittance of the glass using the method above.
- Record on Qualification Test Data Sheet.

3.7.2.2 Part II

- Measure transmittance of a collector glass panel using the method above.
- Ship the collector to a test site near either Phoenix, Arizona or Las Vegas, Nevada.
- Install an exposed position facing due south and tilted at an angle of 25° to the horizontal.

- Age in this position without fluid for 100 to 102 days.
- Return to ERC, Minneapolis.
- Inspect and conduct transmittance tests using the method above.
- Record on Qualification Test Data Sheet.

ATTACHMENT A
Collector Efficiency Detailed Test Procedure
(IPC 1.3.1)

1. Test Levels

- o All efficiency measurements will be made at a simulated solar flux of 220 ± 20 Btu/hr-ft².
- o Transfer fluid will be 50/50, H₂O/Ethylene Glycol. Flow rate of fluid will be 0.35 ± 0.10 gpm.
- o Collector inlet temperature levels will be in accord with the following table.

 $90^{\circ} \pm 2^{\circ}\text{F}$ above ambient temperature
 $125^{\circ} \pm 2^{\circ}\text{F}$ above ambient temperature
 $160^{\circ} \pm 2^{\circ}\text{F}$ above ambient temperature
 $200^{\circ} \pm 2^{\circ}\text{F}$ above ambient temperature

2. Test Facilities

Solar Simulator -- The solar simulator generates a range of flux levels that closely approximates the distribution of the solar spectrum. The simulator consists of 143 projection lamps evenly spaced in a square array containing 13 rows and 9 columns. The output from each lamp is collimated by a 6 inch diameter plastic Fresnel lens set in an array 11 inches in front of the lamp array. Using the Fresnel lenses results in a flux output that is essentially direct radiation, closely simulating actual solar radiation.

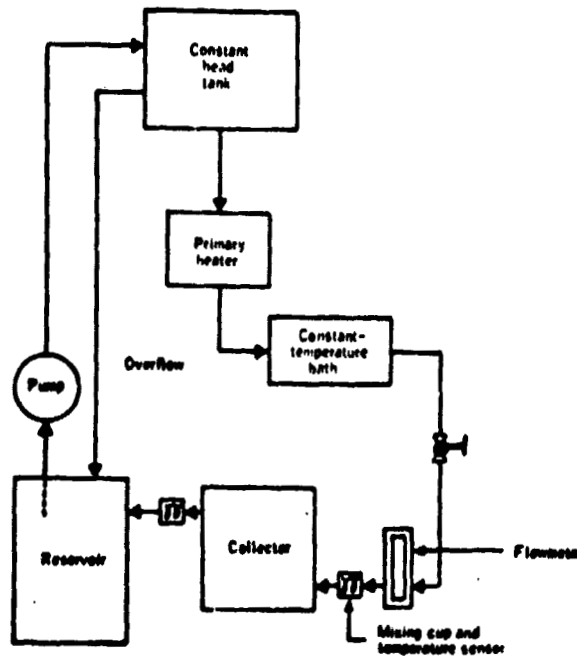
The solar simulator is powered by a 3-phase, 208-volt wye configuration circuit capable of providing 43,000 volt-amperes of power. Each phase of the circuit is monitored by an SCR power controller which restricts the power output from zero to full scale, dependent on an operator-supplied control signal. The full scale output from the solar simulator is 250 Btu/hr-ft^2 at a distance of 15 feet from the lens array. This solar simulator is similar in design to that at the NASA-Lewis Research Center, Cleveland, Ohio.

Flow Loop -- The glycol/water mixture is pumped from the reservoir to a 15 foot constant heat tank. An overflow line to return fluid to the reservoir maintains a constant pressure head. This pressure head drives fluid to a conventional hot water heater and then through a constant temperature bath. From the bath the fluid goes through the flowmeter to the collector. The outlet from the collector returns fluid to the reservoir and completes the cycle. A valve placed between the constant temperature bath and the flowmeter regulates the flow.

Mixing cups are inserted at the inlet and outlet of the collector. A 6-junction thermopile and a thermocouple are placed in each mixing cup. From these, the fluid temperature difference across the panel and fluid inlet and outlet temperatures is found. Another thermocouple placed behind the collector stand measures the ambient temperature. These temperatures are recorded on a digital recorder. Iron-constantan thermocouple wire is used.

The flow rate is determined using a calibrated flowmeter. As the system approaches steady state, the flow rate is maintained at a constant value. This flow rate is also periodically checked by measuring the time for the return fluid to fill a 1 litre graduated cylinder.

See sketch below:



Instrumentation

A. Solar radiation measurement:

1. Pyranometer -- Eppley 8-48
2. Digital recorder -- Doric, Digitrend 210

} Accuracy (calibrated
by Eppley Laboratories)

B. Temperature measurement:

1. Thermopiles -- 6-junction - copper
constantan

accuracy $\pm 0.90^{\circ}\text{F}$

2. Thermocouples -- iron-constantan

C. Flow measurement:

1. Flowmeter - Brooks

accuracy $\pm 1.0\%$

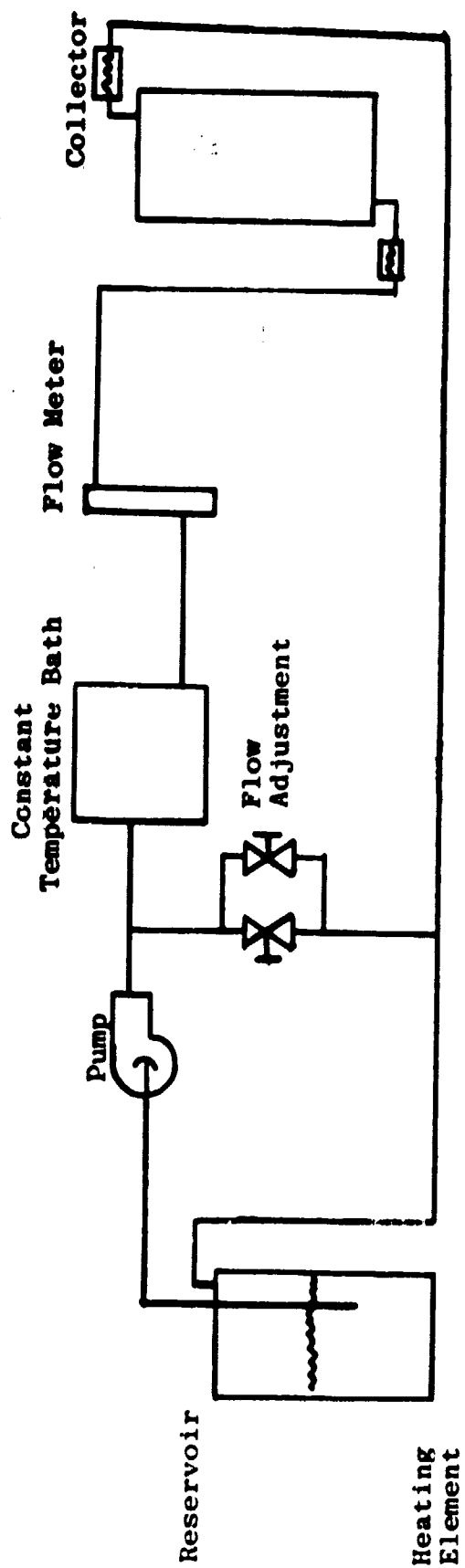
1. Reference NBSIR 74-635 Method of Testing for Rating Solar Collectors
Based on Thermal Performance, Dec. 1974, Paragraph 6.1.

3. Test Procedure

- Mount collector normal to the radiation and at least 8 feet from solar simulator.
- Install thermocouple on and behind absorber plate.
- Connect to flow loop and bleed all air from system.
- Set solar simulator voltage to a level corresponding to 220 Btu/hr - ft² using the simulator calibration curve. Record voltage.
- Measure flux by installing the Eppley pyranometer at each intersection of a six inch grid over the entire surface of the 3 x 6 ft. collector. Average all readings and record on Qualification Data Sheet.
- Note voltage during the above procedure and adjust if necessary to maintain initial voltage set point.

- Set flow control valve to 0.35 gal/min. (11.5 - 13.0 lb/hr-ft²).
- Adjust collector inlet temperature to the first of the four temperature levels.
- Continue to monitor simulator voltage throughout test sequence and adjust if necessary to maintain initial voltage set point.
- When steady state conditions are reached (no measurable change in $T_{f,i}$ or $T_{f,e}$), record the following data for a 15 minute period at 1 minute intervals:
 1. Time
 2. Ambient temperature (T_a)
 3. Flow rate
 4. Collector inlet temperature ($T_{f,i}$)
 5. Collector outlet temperature ($T_{f,e}$)
 6. Plate temperature (T_p)
- Repeat the above measurements for each of the collector inlet temperature conditions.
- Repeat flux measurement using Eppley pyranometer at the beginning and end of each test day.
- Record data on Qualification Test Data Sheet.
- Reduce data by the method of paragraph 8.4 NBSIR 74-635 Method of Testing for Rating Solar Collectors Based on Thermal Performance, December 1974.

Revised:
12 October 1976



Collector Test Flow Loop

QUALIFICATION TEST DATA SHEET

Subsystem	_____	Sheet	_____ of _____
Item Tested	_____	Date	_____
Part No.	_____	Test Engineer	_____
Serial No.	_____	Witnesses	_____
Procedure	_____		_____
		Instrumentation	_____

DATA _____

ATTACHMENT B

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Object of Test

The purpose of this test program is to qualify a solar flat plate collector for use on NASA Contract NAS8-32093. This report satisfies the Data Requirement Item 500-14.

Items Tested

- Four Lennox Model LSC18-1 Solar Collectors serialized as follows:

5876-F-14833
5876-F-14811
5876-F-14836
5876-F-14835

- One Lennox solar absorber plate part number LB-28282A

- Coupon specimens of Lennox solar collector parts as follows:

Collector Pan	P/N	LB28287 B
Seal Strip	P/N	40A2201
Glass	P/N	LB28283D
Frame	P/N	40A2601
Absorber Plate	P/N	LB28282A

Conclusions

The test results reported here in document that the Lennox LSC18-1 collector meets the requirement of contract NAS8-32093.

Procedures

The following tests were conducted in accordance with test plan Doc F3437-T-101.

<u>Test/no.</u>	<u>Item Tested</u>	<u>Objective</u>
Pressure 3.1	Collector-Lennox LSC18-1	Ascertain no leakage under hydrostatic pressure of 150 psig
Service Loads 3.2	Normally supported Collector-Lennox LSC18-1	Determine ability to withstand a distributed load of 50 PSF
Hail 3.3	LSC18-1 Collector with glass-(2) 1/8" tempered P/N LB28284B	Determine ability to withstand impact of 1.25 inch ice sphere at 82 ft/sec.
Solar Degradation 3.4	2 collectors-Lennox LSC18-1	Measure efficiency after 1 month, examine. After 6 months at average 500 langley/day.
Pollutants 3.5	Coupon specimens	Determine if: O ₃ , NaCl, SO ₂ , NO _x , HCl, degrade specimens
Thermal Degradation 3.6	Coupon specimens	Age at max, service temperature
Outgassing 3.7	Collector-Lennox	Determine if outgassing results from: 3 solar simulator cycles & 100 day-nite cycles.

Summary of Results

The following summary of results is a condensation of relevant detailed data obtained during the test. This data is on file at Honeywell. All data sheets are signed by the test engineer and a representative of DCAS (Defense Contractor Auditing Service).

3.1 Pressure Test

The objective of this test was to ascertain the ability of the collector absorber plate to withstand a hydrostatic pressure of 150 psig. The test was conducted on an absorber plate P/N LB28282A.

Test Level: 158 psig

Prerequisite: Less than 1 psi pressure drop in 15 minutes

Examination: No discernable pressure drop after 30 minutes.

3.2 Service Loads

The objective of this test was to determine the ability of the solar collector to withstand a uniform distributed load of 50 psf. The test was conducted on a normally mounted collector S/N 5876-F-14833.

Test Level: 78.5 psf

Prerequisite: No structural degradation or failure which would effect functionability

Examination: No permanent deformation was noted following this exposure.

3.3 Hail

The objective of this test was to determine the ability of the collector to withstand the loads imposed by hail of 1.25 inch diameter and a velocity of 82 ft/sec. The test was conducted on collector S/N 5876-F-14833.

Test Level:

- (1) 1.25 inch diameter 86.96 ft/sec.
- (2) 2.00 inch diameter 107.53 ft/sec.
- (3) 2.50 inch diameter 116.27 ft/sec.
- (4) 3.00 inch diameter 126.58 ft/sec.
- (5) 3.00 inch diameter 131.58 ft/sec.

Prerequisite: No discernable fluid leakage of the collector panel

Examination: No damage due to hail impact on tests 1, 2 and 4. On test number 3 the outer pane of glass shattered. Test number 5 was conducted with a single pane of glass which shattered producing a dent in the absorber panel. A pressure test at 130 psig indicated no leakage.

3.4 Solar Degradation

The purpose of this test is to determine the level of efficiency degradation due to exposure to natural sunlight.

Test Level:

- A. Six months exposure in Phoenix, Arizona
- B. One month exposure in Phoenix, Arizona

Prerequisite: No excessive physical degradation

Examination: Pre exposure efficiency curves are presented in Figures 1 and 2. Post exposure curves are presented in Figures 3 and 4. The efficiency equations are as follows:

	<u>One Month</u>	<u>Six Months</u>
Pre exposure	$0.81 - 0.70 (\Delta T/Q)$	$0.83 - 0.67 (\Delta T/Q)$
Post exposure	$0.73 - 0.58 (\Delta T/Q)$	$0.75 - 0.62 (\Delta T/Q)$

PRE EXPOSURE BASE LINE

LSC-18-1 PERFORMANCE CURVE

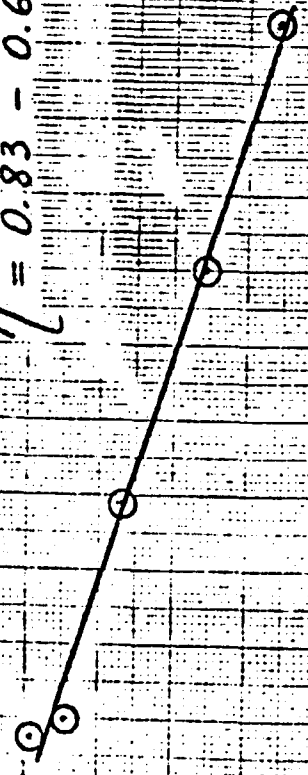
INDOOR TEST (WIND SPEED=0MPH)

$Y(\text{INTERCEPT}) = F_R \tau_c \propto$ SLOPE = $F_R U_L$

$$\eta = (F_R \tau_c \propto) - (F_R U_L) \left(\frac{T_{in} - T_a}{Q_{inc}} \right)$$

$$\eta = 0.83 - 0.67 \left(\frac{T_{in} - T_a}{Q_{inc}} \right)$$

INSTANTANEOUS COLLECTOR EFFICIENCY, %



COLLECTOR SERIAL NUMBER
5876 A 14811

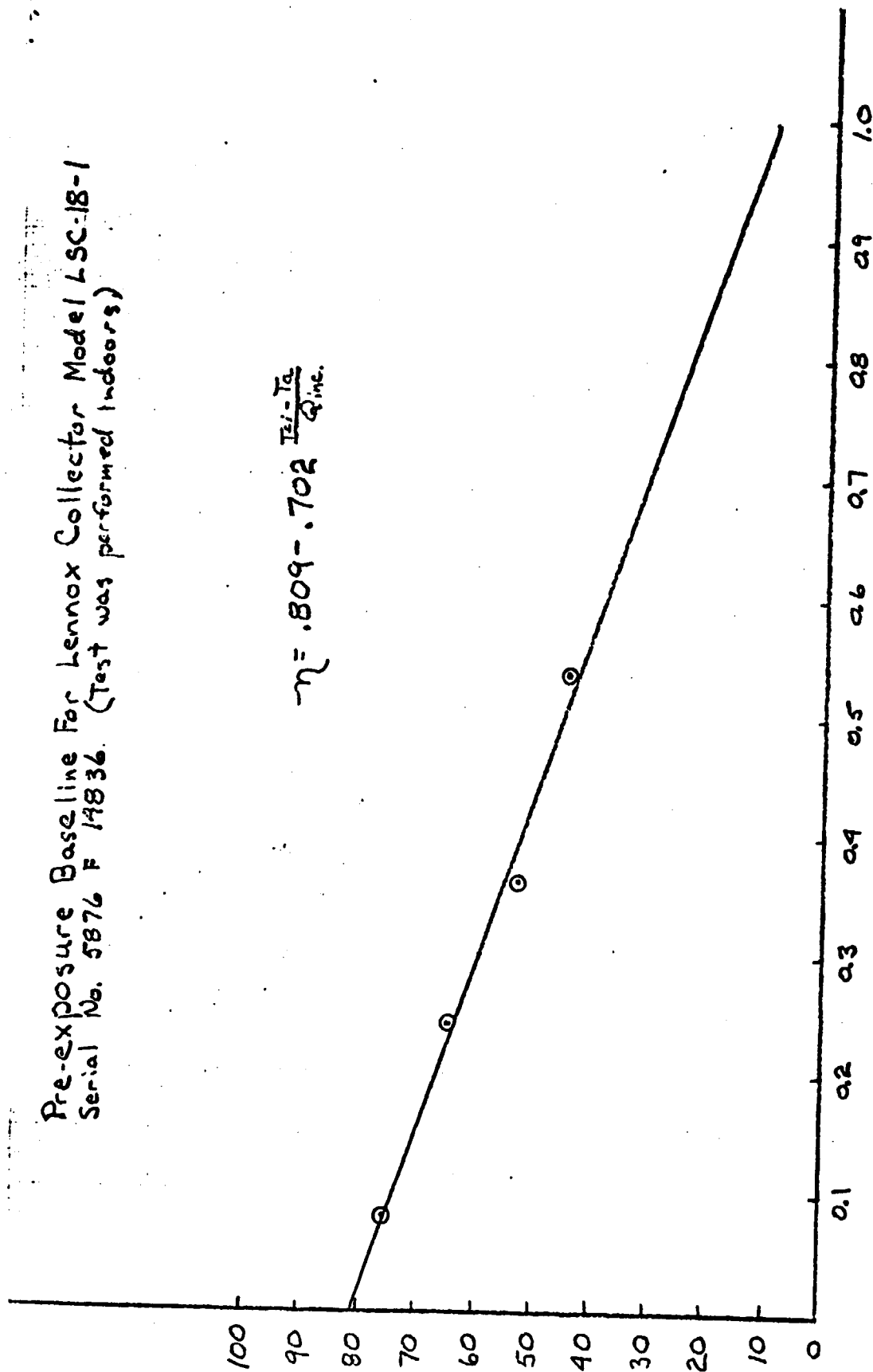
$\frac{T_{in} - T_a}{Q_{inc}} = \frac{F_R \tau_c \propto}{F_R U_L}$

FIGURE 1

Pre-exposure Baseline For Lennox Collector Model LSC-18-1
 Serial No. 5876 F 14836. (Test was performed indoors)

$$\eta = .809 - .702 \frac{T_{fi} - T_a}{Q_{inc.}}$$

Collector Efficiency (%)



$$\frac{T_{fi} - T_a}{Q_{inc}} \left(\frac{^{\circ}F \cdot Hr \cdot Ft^2}{BTU} \right)$$

FIGURE 2

Performance Curve For Lennox L50-B-1 Serial No A811
 After Six Months At Desert Sunshine

Efficiency (%)

$$\frac{T_{in} - T_a}{Q_{in}}$$

$$\eta = .750 - .615 \frac{T_{in} - T_a}{Q_{in}}$$

FIGURE 3

Performance Curve For Liennox LSC-18-1 Serial No 14836
 After Four Weeks At Desert Sunshine

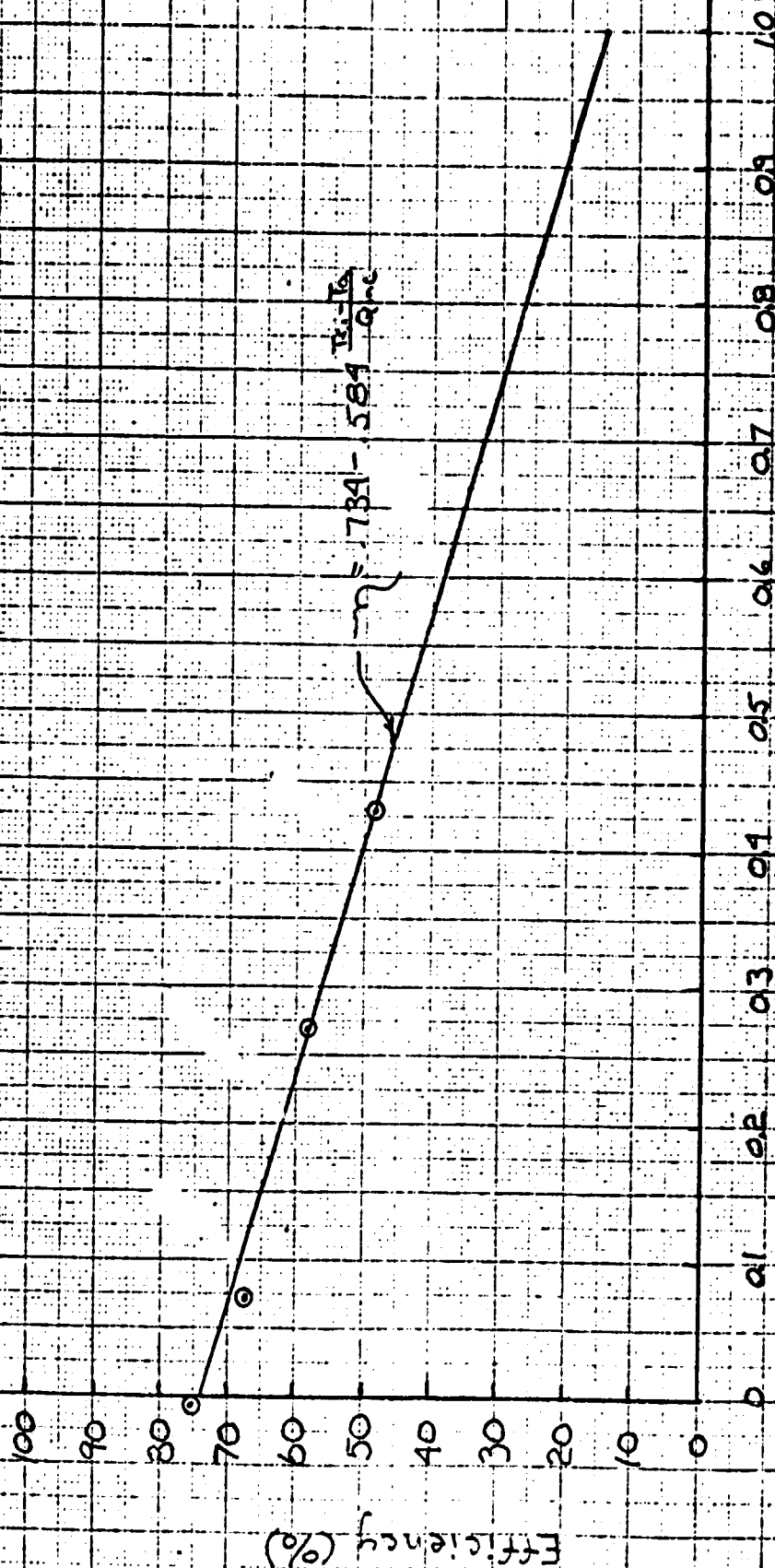


FIGURE 4

3.5 Airborne Pollutants

Coupon specimens of the collector pan, seal strip, glass and frame were each subjected to a 500 hour exposure of the following pollutants:

- (1) Ozone**
- (2) Salt spray**
- (3) Sulfurous acid**
- (4) Nitric acid**
- (5) Hydrochloric acid**

Each exposure is treated separately below:

A. Ozone

The four coupon specimens were subjected to an ozone atmosphere. The objective was to determine if degradation occurred after 500 hours at an ozone concentration of 50 pphm.

Test Level: 42.5 - 58.0 pphm

**Prerequisite: Finish - no degradation
Transmittance - less than 10% degradation
Seal strength - less than 40% degradation**

**Examination: Collector pan - no change in appearance
Seal strip - original tensile strength 47.916
 final tensile strength 46.516
 degradation 3%
Glass - pretest transmittance 93.9%
 post test transmittance 93.4%
 degradation 0.5%
Frame - no change in appearance**

B. Salt Spray

The same four coupon specimens were subjected to a salt spray test in accordance with ASTM Method B-117-73.

Test Level: 500 hours at 95° F

Prerequisite: Finish - no degradation
Transmittance - less than 10% degradation
Seal strength less than 40% degradation

Examination: Collector pan - no degradation
Seal strip - original strength 47.9 lb
 final strength 48.8 lb
 degradation - 4%*
Glass - pretest transmittance 94.3%
 post test transmittance 94.1%
 degradation 0.2%
Frame - no degradation

C. Sulfurous Acid

This exposure of the coupon specimens is intended to simulate airborne sulfur based pollutants.

Test Level: 500 hours 100 ppm acid

Prerequisite: Finish - no degradation
Transmittance - less than 10% degradation
Seal strength - less than 40% degradation

Examination: Collector pan - no significant degradation
Seal strip - original strength 47.91 lb
 final strength 52.91 lb
 degradation - 10%
Glass - pretest transmittance 94.9%
 post test transmittance 93.8%
 degradation 1.1%
Frame - no significant degradation

* perceived increase in strength is probably within the tolerance of the test method.

D. Nitric Acid

This exposure of the coupon specimens is intended to simulate the effect of Nitrous oxide products in the air.

Test Level: 500 hours at 100 ppm acid

**Prerequisite: Finish - no degradation
Transmittance - less than 10% degradation
Seal strength - less than 40% degradation**

**Examination: Collector pan - no significant degradation
Seal strength - original 47.9 lb
 final 49.9 lb
 degradation -0.4%
Glass - pretest transmittance 96.0%
 post test transmittance 94.1%
 degradation 1.9%
Frame - no significant degradation**

E. Hydrochloric Acid

This exposure of the coupon samples is to simulate airborne hydrochloric acid.

Test Level: 500 hours 100 ppm acid

**Prerequisite: Finish - no degradation
Transmittance - less than 10% degradation
Seal strength - less than 40% degradation**

**Examination: Collector pan - no significant degradation
Seal strip - original strength 47.9
 final strength 47.8
 degradation < 0.1%
Glass - pretest transmittance 93.9%
 post test transmittance 93.8%
 degradation 0.1%
Frame - no significant degradation**

3.6 Thermal Degradation

Coupon specimens of the glass, seal strip and frame were subjected to an exposure of 280°F for 500 hours. A coupon specimen of the absorber plate was subjected to an exposure of 480°F for 500 hours. These levels were derived from the HUD Interim Performance Criteria. Figure A-3 p. 55, Temperatures at Various Locations in a Collector with a Selective Absorber and Two Glass Cover Plates.

Test Levels: 500 hours

Prerequisite: Finish - no significant degradation
Transmittance - less than 10% degradation
Seal strength - less than 40% degradation

Examination: Absorber Plate - original absorptance 90.0
original emittance 8.7
final absorptance 86.6
final emittance 8.0

Frame - no degradation

Glass - pretest transmittance 94.3
post test transmittance 94.4
degradation -0.1%

Seal strip - after exposure at 280°F the seal strip was so brittle that it was not possible to conduct a strength test on it.

Seal Strip Failure Analysis

An investigation of actual temperatures encountered by the seal strip was conducted at the test site in Phoenix, Arizona. A report of this investigation in the form of a letter from Desert Sunshine Exposure Tests is included here as Figure 5. This data allowed the conclusion that 150°F would be a more realistic test level for the seal strip.

DESERT SUNSHINE EXPOSURE TESTS, INC.

We Test Anything Under the Sun

BOX 185 • BLACK CANYON STAGE
PHOENIX, ARIZONA 85020
(602)465-7525



TAWA
THE SUN KACHINA

February 2, 1977

Mr. Al Baldwin
MORELL, INC.
724 Harding Street N.F.
Minneapolis, Minnesota 55413

Dear Mr. Baldwin:

Listed below are the temperature measurements, and corresponding information, taken on the Honeywell collector coded S/N F14835, covered by Purchase Order #416592-XA, our Order No. 17225.

Date	Time	Ambient	Point	Temp.	Insolation
1/28/77	1:00 p.m.	17.0°C	22	54.5°C	1.44 lys/min
				Maximum Plate Temperature = 195.8°C at 12:51 pm	
1/28/77	1:00 p.m.	17.0°C	23	52.0°C	1.44 lys/min
1/29/77	11:45 a.m.	17.0°C	22	40.5°C	0.80 lys/min-Cloudy
1/29/77	11:45 a.m.	17.0°C	23	37.5°C	0.80 lys/min-Cloudy
1/30/77	1:00 p.m.	18.0°C	22	51.5°C	1.49 lys/min
1/30/77	1:00 p.m.	18.0°C	23	48.0°C	1.49 lys/min
1/31/77	12:30 p.m.	18.5°C	22	55.5°C	1.52 lys/min
1/31/77	12:30 p.m.	18.5°C	23	52.0°C	1.53 lys/min
				Maximum Plate Temperature = 202.2°C at 12:30 pm	

Point #22 = Between Rubber and Glass - Inner Glass
Point #23 = Between Rubber and Aluminum Frame - Inner Glass

If you should have any questions regarding these data, please contact us.

Very truly yours,

Thomas E. Anderson
Thomas E. Anderson
Weathering Manager

TEA:lf

Seal Strip Corrective Action

The seal strip coupon specimen was retested at a level of 150°F for 500 hours. The result of post test examination is as follows:

pretest strength	47.9 lb
post test strength	45.5 lb
degradation	2.1%

3.7 Outgassing

The objective of this test was to determine if the outgassing of organic material within the collector during solar cycling has an adverse effect on performance. The test sequence is as follows:

- Transmittance measurement of the glass
- Three cycles from 0 to 250 Btu/hr-ft² on a solar simulator
- Transmittance measurement of the glass
- 100 days of natural cycling in Phoenix, Arizona
- Transmittance measurement of the glass

Test Levels: 250 Btu/hr-ft² Solar Simulator, Natural Sunlight,
Phoenix

Prerequisites: less than 10% degradation of transmittance

Examination: pretest transmittance 87.5
post simulator transmittance 85.4
post sunlight transmittance - 84.6
total degradation due to outgassing was 2.9
percentage points or 3.3%